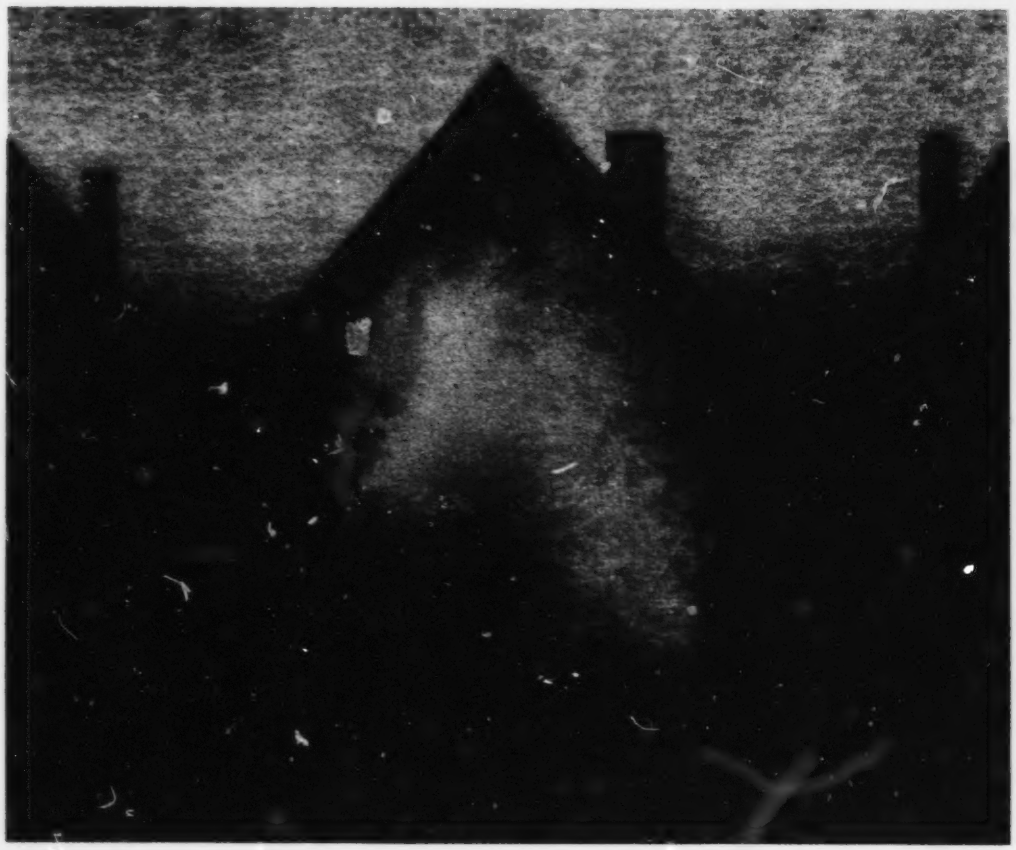
Alberta Energy

Scientific and Engineering Services

Some Methods of Insulating Basements, Walls and Windows

Projects supported in part by the Alberta/Canada Energy Resources Research Fund



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Foreword

Since 1976, numerous projects have been initiated in Alberta by industry and by academic research institutions which are aimed at better utilization of Alberta's energy resources.

These research, development and demonstration efforts were funded by the Alberta/Canada Energy Resources Research Fund (A/CERRF), which was established as a result of the 1974 agreement on oil prices between the federal government and the producing provinces.

Responsibility for applying and administering the fund rests with the A/CERRF Committee, made up of senior Alberta and federal government officials.

A/CERRF program priorities have focused on coal, energy conservation and renewable energy and conventional energy resources. Administration for the program is provided by staff within the Scientific and Engineering Services and Research Division of Alberta Energy.

In order to make research results available to industry and others who can use the information, highlights of studies are reported in a series of technology transfer booklets. For more information about other publications in the series, please refer to page 10.

Some Methods of Insulating Basements, Walls and Windows

The amount of heat lost from residential buildings by conduction through walls, doors and windows can be reduced by adding insulating materials to the walls and by choosing types of windows and doors that conduct very little heat.

While substantial research effort has been directed at development of insulating techniques and materials suitable for new homes, owners of existing homes are not being provided with all the advice they need to make informed choices about energy-conserving options.

To help provide some of this needed guidance, three A/CERRF-funded projects were initiated which deal with practical comparisons of various types of exterior basement insulation, an evaluation of optional systems that might be used to upgrade the insulating characteristics of existing walls and development of an insulating curtain for windows.

Methods of Adding Insulation to Basement Walls

Approximately one-third of the heat lost from residential buildings is conducted outdoors through the floor and walls of uninsulated basements. To stem this flow, basements can be insulated on the inside or the outside surfaces of the walls using a variety of materials.

According to the principles of building physics, the ideal location for insulation is on the cold (or outside) surface of walls, while air/vapor barriers, if required, should be installed on the warm (or inside) surface to minimize problems caused by moisture and deterioration of walls. Nevertheless, insulating on the inside can be easier and less expensive in unfinished basements.

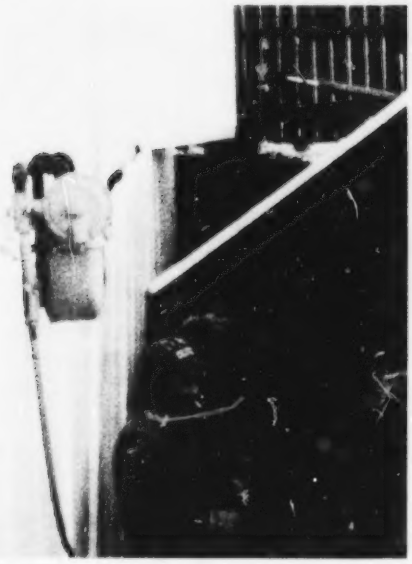
To compare the energy savings available by insulating either the inside or outside of basement walls, Dow Chemical Canada Inc. carried out a study in which five owner-occupied homes (four in Edmonton, one in Calgary) received different insulation treatments. Then, for one year after insulating, home heating bills were compared with bills for one year before insulating.

Homes chosen for the project were required to meet certain conditions such as having a full-depth basement, relatively easy access to foundation walls and no insulation on the basement walls, as well as having had no energy conservation improvements for at least one year before the project began and for one year after retrofitting.

Basement Insulation Treatments

Occupied Home	Treatment	RSI	R
1	Full height application of extruded polystyrene sheathing on the basement exterior	2.20	12.5
2	Full height application of batt-type insulation on the basement interior	2.11	12.0
3	Full height application of rigid glass fibre insulation on the basement exterior	2.99	17.0
4	Full height application of extruded polystyrene sheathing on the basement interior	2.20	12.5
5	Application of rigid expanded polystyrene sheathing on the basement exterior	2.15	12.3

(Source: *Energy Savings and Payback with Basement Wall Insulation Retrofit*, D.S. Greeley, Dow Chemical Canada Inc., December 1986)



Exterior installation of rigid insulation (left), and the finished results (right).

(Photos courtesy of Dow Chemical Canada Inc.)

Three of the homes were insulated on the outside while the other two were retrofitted on the inside. In every case, the work was performed by contractors. No attempt was made to encourage homeowners to change their energy consumption patterns during the project.

Energy consumption data obtained from heating bills were adjusted for heating degree days and then were normalized by multiplying them by the ratio of mean yearly heating degree days to actual heating degree days. This produced values for "adjusted energy usage," which allowed direct comparison of results for different time periods.

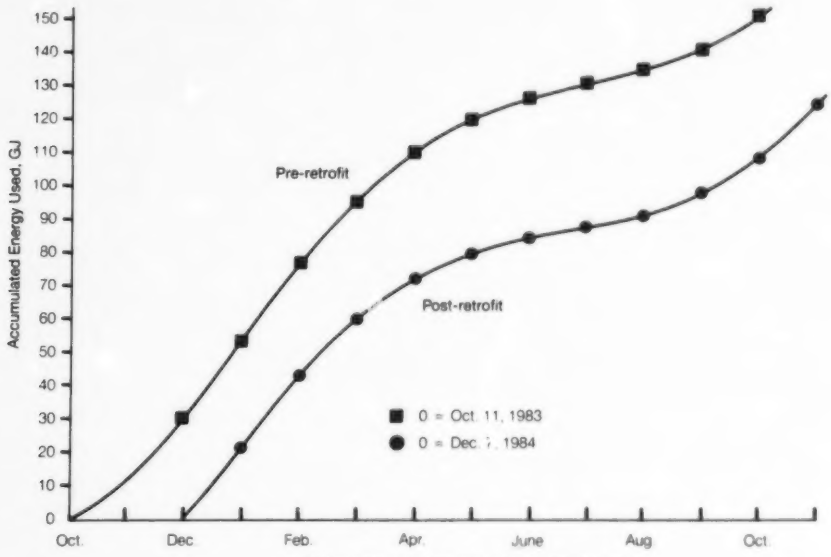
It was found that fuel cost savings varied from $68 to $233 a year, representing energy savings of from 15 to 51 gigajoules. No firm conclusions could be reached about the impact of specific treatments because the experiment did not control such factors as differences in solar gain, variations in energy use for hot water and overall lifestyles of the individual homeowners, all of which may have influenced the results.

The costs to install the various types of insulation ranged from $3 200 to $3 500 for interior retrofits and from $4 200 to $4 600 for exterior work, resulting in payback periods of from 13 to 68 years. Approximately 30 per cent of the installation costs could have been saved if homeowners had provided all the necessary labor, in which case payback periods could have ranged from nine to 44 years. While the calculation of simple payback period does not consider indirect benefits such as increased future worth of homes, higher resale values and enjoyment of more comfortable living spaces, significant energy savings can result from basement retrofits. Whether those savings are manifested in lower heating bills and reasonably short payback periods will depend upon the overall energy-consuming habits of individual homeowners. This is borne out by other studies which have resulted in five-year payback periods when insulation was applied to the interior of basement walls.

A separate study was conducted at the Alberta Home Heating Research Facility of the University of Alberta to determine the heat loss reduction that is possible by insulating basements on the outside with rigid polystyrene. In this investigation, the thermal performance of an uninsulated basement was compared with one that was insulated, using two of the unoccupied test modules at the facility, each of which has concrete basement walls.

Rates of heat transfer through the uninsulated and externally insulated (RSI 1.76; R10) basement walls were measured for 16 months using heat flux transducers and mimic boxes. The latter, which were developed by the National Research Council, measure heat transfer through a portion of a wall and are heated independently of the surrounding room to maintain the box interior at the same temperature as the room. As a result, the energy needed to heat the mimic box can be assumed to be equal to heat losses through the portion of the wall covered by the box.

Normalized Energy Usage



Typical energy performance data for a test home, before and after basement insulation

(Source: *Energy Savings and Payback with Basement Wall Insulation Retrofit*, D.S. Greeley, Dow Chemical Canada Inc., December 1986)

Heat flux transducers, developed by the University of Alberta, were attached to the walls at 500 mm (20 in.) intervals to allow measurement of heat loss at various positions on the walls. Measured heat losses were compared with values predicted by the National Research Council's HOTCAN computer program and a finite element computer program developed by Dow.

The results showed that heat loss through the below-grade portion of basement walls can be reduced substantially by applying insulation on the outside surface. Heat flux transducer measurements showed a 65 per cent reduction, whereas mimic boxes measured a 60 per cent drop. By comparison, the HOTCAN and finite element computer programs predicted a heat loss reduction of 66 and 70 per cent, respectively.

In view of these findings, it appears that adding basement wall insulation to existing homes is not economic, particularly when the work is performed by contractors, but the potential for considerably lower heat losses seems to warrant the addition of basement wall insulation to new homes while they are under construction. Some homeowners, however, may choose to retrofit their basement walls simply because of the added comfort made possible by higher levels of insulation.

Retrofit Wall Systems for Residential Buildings

Over a period of two years, ARE - Alternative & Retrofit Energies Inc. of Calgary evaluated 15 wall insulation systems that can be retrofitted to the exterior, above-ground walls of residential buildings.

Each system was ranked according to its ability to satisfy 52 criteria, which the investigators chose on the basis of their own experience and suggestions made by contacts within the residential construction industry. The criteria were wide-ranging and covered such aspects as insulation properties, costs and installation characteristics. For example, wall systems were rated on the basis of R-value per inch of thickness, air and water vapor permeability, the ability to be used with standard construction techniques, impact resistance, ease of repair and cost-effectiveness.

The investigators assigned points to each criterion in a subjective, but informed, manner to produce a comparative inventory graph; the higher the point score the better the overall suitability of the retrofit wall system.

Those retrofit wall systems that were evaluated were subdivided into three general classes, as follows:

1. **Rigid Sheathing**
   a) Isocyanurate (Thermax)
   b) Extruded Polystyrene (Styrofoam SM)
   c) Expanded Polystyrene (EPS)
   d) Rigid Fibreglass (Glasclad)
   e) Phenolic Board (Esclad)
2. **Curtain Wall**
   a) Spacer Block
      i) Double Wall
      ii) LeClaire Wall
      iii) Piggyback Wall
      iv) Standoff Wall
      v) Metal Extender Wall
      vi) TEC Wall
   b) Prefabricated
      i) TJI Floor/Roof Truss
      ii) Larsen Truss
      iii) Ecostud
3. **Spray-On**
   a) Polyurethane

Analysis of the criteria ranking in the Comparative Inventory Chart (a short form, which lists 18 of the most important criteria, is shown here) revealed that expanded polystyrene sheathing (EPS) is superior to other wall insulation systems; however, the TEC Curtain-Wall System was a close second.

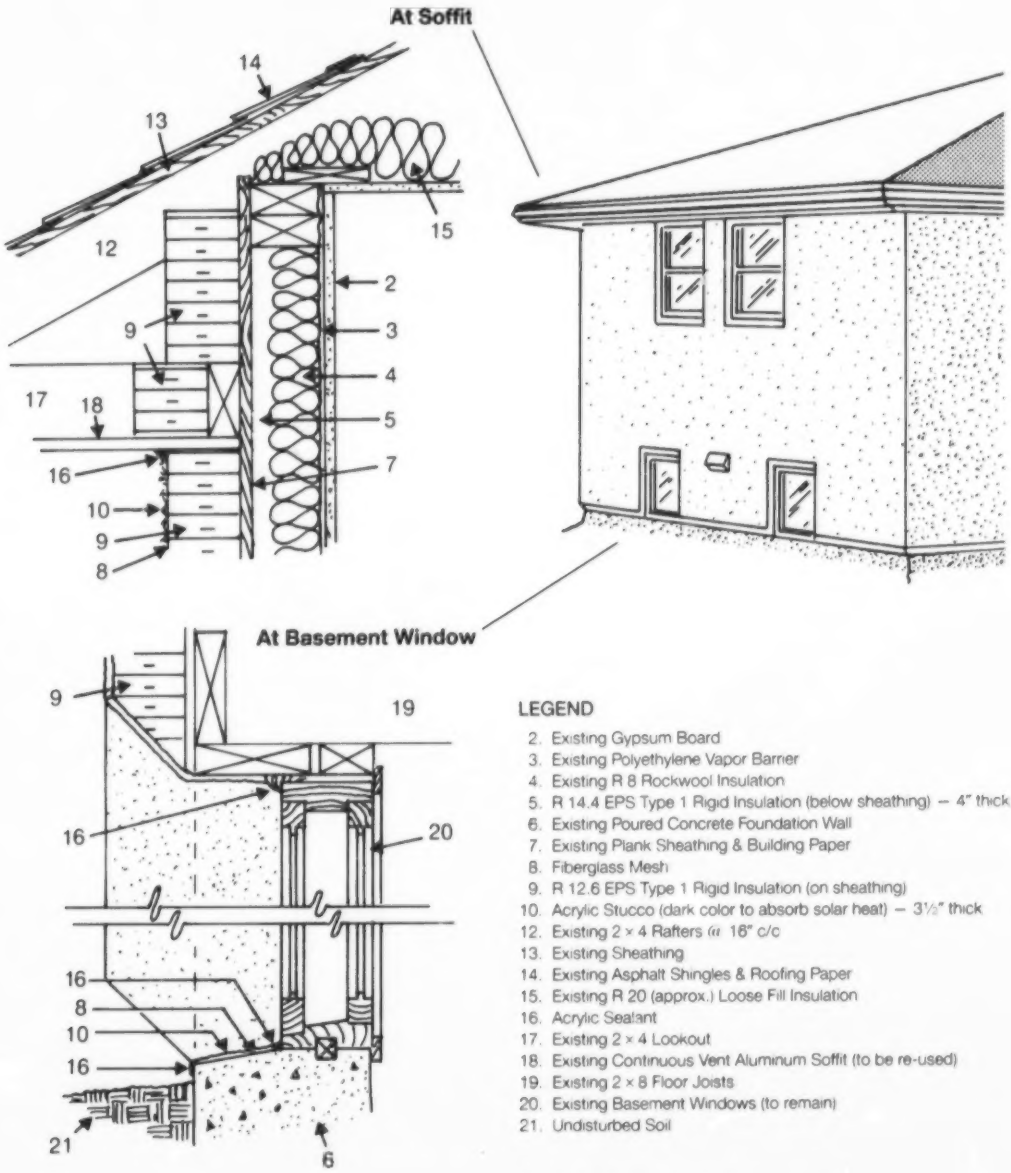
The investigators' report, entitled "Retrofit Wall System for Residential Housing," is well-illustrated with photographs and diagrams of individual wall systems, including photographs of actual installations during various stages of construction. The report also describes in detail the advantages and disadvantages of the three most suitable systems. For example, expanded polystyrene sheathing can be used with standard construction techniques, it is airtight but vapor-permeable, it may be cut and quickly applied, it can serve as a base for stucco finishes, it provides a continuous thermal break, it fits easily around windows and doors and it costs less than any of the wall systems evaluated in this investigation. Also, it is simple to install, making it possible for homeowners who have some carpentry skills to do their own retrofit work.

Despite these advantages, however, there may be occasions when other wall insulation techniques are better suited to the particular requirements of a retrofit project. In those cases, the TEC Curtain Wall System may be a suitable choice. Generally, in a curtain wall system, an extra wall is attached to, and built out from, the existing exterior wall. Some types of curtain walls are built on-site, while others are delivered to the work site in prefabricated form. Once the curtain wall is in place, the cavity between it and the original exterior wall is filled with insulation, such as fibreglass batts or loose-fill cellulose. Vapor/air barriers may be added, as required.

The advantages of the TEC system include: the use of simpler construction techniques than are required by other curtain walls, greater flexibility around doors and windows, fewer gaps that cannot be filled with insulation and no need for special installation equipment.

In some situations, spray-on polyurethane foam (ranked fifth overall in this study) may be appropriate. This material, which is more commonly used to insulate industrial storage tanks and pipelines, is sprayed on in layers until the desired thickness (or R-value) is achieved. It has several advantages, such as a high R-value (which permits a relatively thin coating of insulation), it is airtight, it has continuous thermal break characteristics, it has a high impact resistance and it can be easily applied around doors and windows.

EPS Retrofit Wall System:
Examples of Construction Details



LEGEND

2. Existing Gypsum Board
3. Existing Polyethylene Vapor Barrier
4. Existing R 8 Rockwool Insulation
5. R 14.4 EPS Type 1 Rigid Insulation (below sheathing) – 4" thick
6. Existing Poured Concrete Foundation Wall
7. Existing Plank Sheathing & Building Paper
8. Fiberglass Mesh
9. R 12.6 EPS Type 1 Rigid Insulation (on sheathing)
10. Acrylic Stucco (dark color to absorb solar heat) – 3½" thick
12. Existing 2 × 4 Rafters @ 16" c/c
13. Existing Sheathing
14. Existing Asphalt Shingles & Roofing Paper
15. Existing R 20 (approx.) Loose Fill Insulation
16. Acrylic Sealant
17. Existing 2 × 4 Lookout
18. Existing Continuous Vent Aluminum Soffit (to be re-used)
19. Existing 2 × 8 Floor Joists
20. Existing Basement Windows (to remain)
21. Undisturbed Soil

(Source: *Retrofit Wall System for Residential Housing*, ARE - Alternative & Retrofit Energies Inc., 1986)

After assessing the characteristics of the 15 wall insulation systems included in this study, the investigators concluded that an ideal retrofit wall system should possess certain features. The insulation component should:

a) have as high an R-value as possible
b) act as an air barrier
c) not retard vapor movement
d) allow direct application of stucco
e) be capable of sculpturing
f) achieve RSI 4.2 (R24) in only one layer
g) be produced from biodegradable materials
h) provide a continuous thermal break
i) not degrade under ultraviolet light
j) not be the source of any health risks
k) be capable of application in any weather condition.

The complete wall system should:

a) use standard construction techniques
b) involve a simple construction process
c) not require special equipment, unusual materials, extra sheathing or more than one trade
d) retain doors and windows in their existing positions
e) be suitable for exterior basement retrofit work
f) be versatile enough to accommodate special building situations and R-value requirements
g) use materials that are readily available, biodegradable and produced from renewable resources
h) be suitable for new construction
i) be no thicker than 100 to 125 mm (four to five in.)

Contractors and individual homeowners who are contemplating the addition of insulation to existing buildings would be well advised to consult the investigators' report.

Retrofit Wall System Comparative Inventory Chart (Short Form)

04 = BEST 02 = AVERAGE 00 = WORST	RETROFIT WALL SYSTEMS	EPS (White Styrofoam)	ESCLAD	GLASCLAD	SM (Blue Styrofoam)	THERMAX	Double Wall	LeClaire	Piggyback	Standoff	TEC	Metal Extender	Ecostud	Larsen Truss	TJI Floor/Roof Truss	Polyurethane Spray
CRITERIA		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1.	R-value/inch	02	02	02	02	04	00	00	00	00	00	00	00	00	00	04
2.	Number of layers	04	00	00	02	02	04	04	04	04	04	04	04	04	04	04
3.	Air Barrier	04	04	04	04	04	00	00	00	00	00	00	00	00	00	04
4.	Permeance	04	00	04	00	00	04	04	04	04	04	04	04	04	04	02
5.	Air Movement	04	04	04	04	04	00	00	00	00	00	00	00	00	00	04
6.	Accept Stucco	04	00	00	02	00	00	00	00	00	00	00	00	00	00	04
7.	Additional Sheathing	04	00	00	02	00	00	00	00	00	00	00	00	00	00	04
8.	Standard Construction	04	04	04	04	04	02	02	00	00	02	00	02	02	02	00
9.	One Trade	04	04	04	04	04	04	04	04	04	04	04	04	04	04	04
10.	Special Equipment	04	04	04	04	04	04	02	02	02	04	02	02	02	04	00
11.	Basement Retrofit	04	04	02	04	02	00	00	00	00	00	00	00	00	00	04
12.	Windows Retained	02	02	02	02	04	00	00	00	00	00	00	00	00	00	04
13.	Setback Problems	02	02	02	02	04	00	00	00	00	00	00	00	00	00	04
14.	Impact Resistance	02	04	04	04	04	04	04	04	04	04	04	04	04	04	02
15.	Thermal Break	04	02	02	02	02	02	02	02	02	02	00	00	00	00	04
16.	New Construction	04	04	04	04	04	02	02	00	00	02	00	04	02	02	02
17.	Criteria Rating Total	56	40	42	44	46	24	22	18	20	26	18	24	22	24	50
18.	Cost Effectiveness*	11	57	47	68	69	34	26	30	28	79	42	30	32	33	63
19.	OVERALL RANKING	1	6	7	4	3	9	14	11	13	2	8	12	11	10	5

Criteria rating per cost in cents per square foot per R-value. The higher the number the more cost effective the system.

(Source: *Retrofit Wall System for Residential Housing*, ARE - Alternative & Retrofit Energies Inc., 1986)

Development of an Insulating Curtain

One of the paradoxes that is evident in home construction today is a trend toward better insulation in walls and roofs while, at the same time, the area occupied by poorly insulated windows is increasing, particularly in passive solar homes. This situation, where dwellings have RSI 7 (R40) walls and large expanses of RSI 0.3 (R1.8) glass, points out the need for research activity aimed at improving the energy performance of glazed areas.

Recent developments in window glazing products that reflect radiative heat back inside the home offer some improvement. However, they suffer from disadvantages of high cost, reduced solar gain and an inability to respond to the retrofit needs of existing housing.

An alternative might be to use shutter arrangements on the outside of windows, but they tend to be thick and heavy devices which are costly, do not provide a good seal and are limited in size application.

Attempts to design indoor shutters have been limited by their weight and bulk. However, one material which is thought to be capable of adequate thermal performance, without being heavy or bulky, is thin aluminized plastic which can be purchased as a film or as a fabric laminate. Because this material looked as though it could be used in an insulating curtain, Sunergy Systems Ltd. of Cremona was contracted to design and construct a line of products which could be used on existing windows to reduce heat losses, control unwanted solar gain, provide privacy as required and be aesthetically pleasing.

In designing the curtain, it was recognized that it would be necessary to impede radiative heat transfer and suppress convective heat losses between the room interior and the window. This meant that effective air sealing was required around all four edges of the curtain because even a 3 mm (⅛ in.) air gap on the sides can reduce by 30 per cent the insulating value of a curtain on a small window.

The insulating curtain that resulted from this project is more complex than it first appears. Although it is rolled up and down like a blind, the hardware it uses, along with requirements for edge-sealing, imposes certain limitations on both its design and operation.

Early on in the design process, the need to produce a curtain that could be mounted either above windows or inside window wells led to the discovery that commercially available curtain cords, bead and pocket assemblies and wall mounts were unsatisfactory. Consequently, it became necessary to design and fabricate all these components in-house.

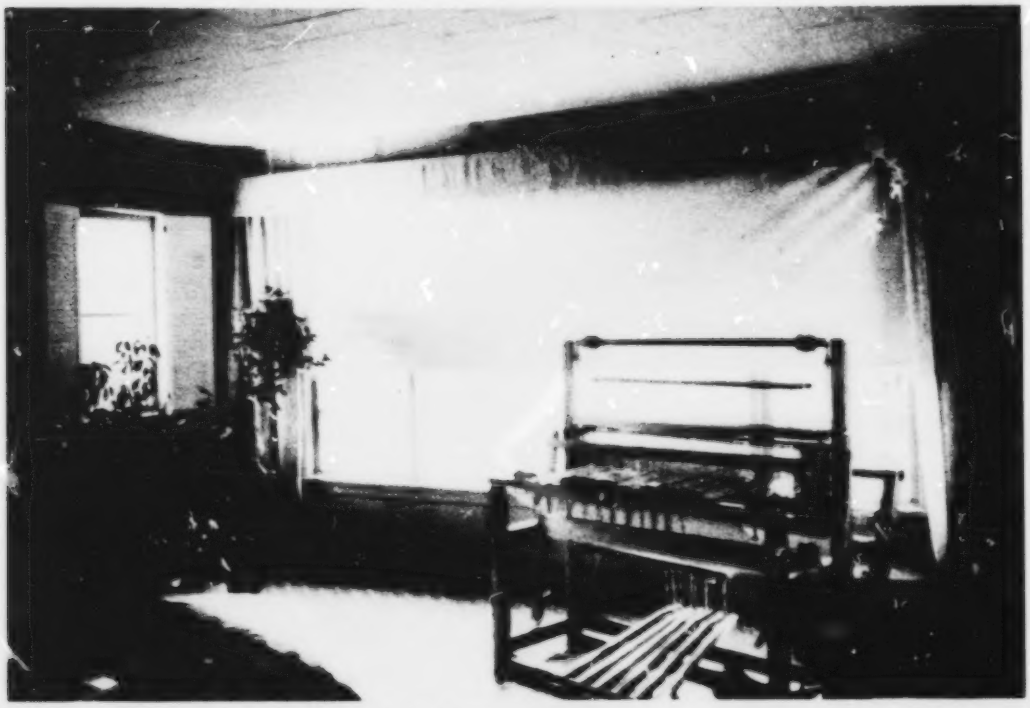
The end result was a valance box in which the curtain was hung prior to installation and contained all the moving parts. Also, the compact nature of the curtain allows it to be installed behind existing draperies.

Considerable design effort was required to perfect an adequate edge-sealing system. Experimentation showed that a "bubble-seal" arrangement on the bottom of the curtain, whereby the curtain material conforms to the contour of the window sill or the floor, was adequate for bottom sealing.

Top sealing was achieved by installing a flap above the roller mechanism and attaching it to the valance box. Side seals, however, were a more difficult challenge.

Several side-sealing techniques were tried before problems such as curtain binding and sagging could be overcome. Hook tracks, magnetic side seals and the use of a plastic edge along both sides were tried and discarded before a "T-track" concept was found to be an acceptable method of keeping the fabric in contact with the wall or window casing.

To satisfy aesthetic requirements, while providing acceptable thermal characteristics, a double-layer curtain configuration was chosen. The outer layer is aluminized ripstop nylon (ARN), which presents a bronze-colored surface to the outside to fulfil reflective requirements. Adjacent to the ARN layer is a lightweight decorative fabric that faces inside. Experience has shown that a 50 per cent polyester/50 per cent cotton, permanent press, washable and pre-shrunk fabric performs well. For higher insulation values, another layer of ARN (with either white or bronze exposed), or an aluminized stitch laminate fabric may be substituted as the interior layer.



SunSeal insulating curtains can be used with a variety of window sizes and shapes. (Photo courtesy of Sunergy Systems Ltd.)

The final product line, known as SunSeal, is adaptable to large glazed areas. Some windows six metres (20 feet) wide by three metres (10 feet) high were successfully insulated. Even bow window arrangements and vertically angled windows can be insulated in this manner. With the advent of small motors, which can be inserted inside tubes as small as 31 mm (1¼ inch) in diameter, it is possible to motorize the operation of the curtains and cause them to be raised or lowered automatically using timers, thermostats or photocells. Where designs permit, insulating curtains can be installed between the layers of glass in double-glazed windows.

As long as the curtains are in a closed position, little transfer of warm moist air will occur between the interior of a home and window glass. However, some condensation can occur soon after the curtain is raised and until the glass temperature rises. Experience with SunSeal curtains has not revealed any problems with thermal stressing when the curtain is raised and the glass is exposed to room temperature.

Thermal testing of the curtains was not undertaken during the time allotted to this project; however, based on earlier work, it was estimated that RSI 0.9 or 1.1 (R5 or 6) should be expected in most applications.

Contacts

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